Improving Production Capacity and Coefficient Efficiency of K-Contactor in the Backend Process: A Simulation Case Study

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Abstract. This research was conducted in an electrical company that aims to increase production capacity due to a surge in demand. The demand is 8% year to year increasing, especially for K-Contactor products. The company also wants to improve the Coefficient Efficiency rate towards 80%; currently, it is between 65-75%. A simulation model was constructed using Pro-Model to imitate the current condition and to simulate the proposed solution. By arranging the layout of the machine, the target production is increased from 325 to 334 and the coefficient efficiency of K-contactors reaches 80%.

Keywords: Simulation, coefficient efficiency, working sampling, time motion study, facility layout.

1 Introduction

A contactor is an electrical device that switches an electrical circuit on or off. It is frequently employed when a high-power load needs to be managed, such as in industrial machinery, HVAC systems, lighting systems, and other equipment. Contactors are designed to handle higher currents and voltages than regular switches, which are often used for lower-power applications [1]. The basic principle of a contactor involves an electromagnetically controlled switch mechanism. It consists of a coil that, when energized, generates a magnetic field, which in turn pulls in a set of contacts. These contacts are extensive and robust enough to handle the current and voltage requirements of the connected load. When the coil is de-energized, the magnetic field collapses, and the contacts return to their original positions, opening or closing the circuit as needed [2].

A multinational company located in Indonesia produces contactors marketed as K-contactors. The production process of this K-contactor goes through several lines. The production process is mainly done manually (by humans). However, the last process, the so-called backend line, is automatic. It consists of product testing and packaging. Since the demand for the K-contactor is increasing by 8%, the company wants to increase the backend process from 325 pcs/hour to 340 pcs/hour. Increasing the output

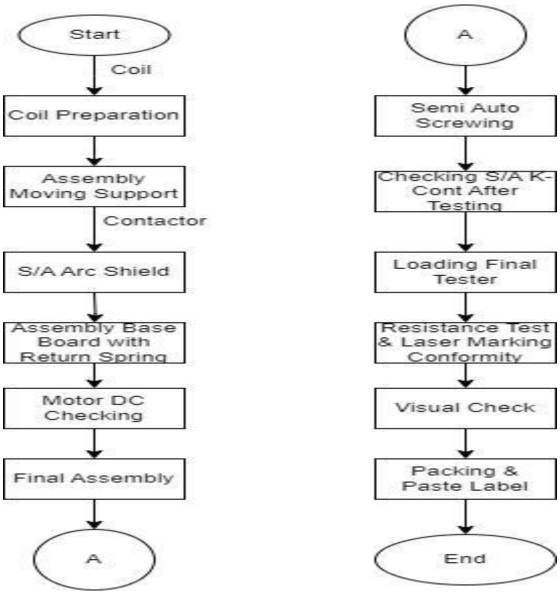


Fig 1. K-Contactor's backend production process

means increasing the percentage of the efficiency coefficient. Currently, the efficiency coefficient is 65-75%. The company wants to increase it to 80%. Therefore, the company wants to increase the productivity in the K-contactor production line.

There are some strategies for increasing productivity, e.g., reducing downtime, increasing employee hours, improving internal processes, and improving the layout [3]. Some methods can be implemented for increasing productivity, e.g., lean manufacturing, total productive maintenance [4], value stream mapping [5], using worker position data [6] and simulation [7]. In this study, arranging the layout of the machines, i.e., robots, for increasing the production capacity is chosen, particularly in the last process, the so-called backend line. This line is fully automatic. However, before the proposed layout is implemented, the model layout is simulated in advance.

2 Methods

In the methods section we explain about the data collection and preparation, and the model construction.

2.1 Collecting Data

The data collected in this study is the working time of a qualified and well-trained worker to complete every single process in the K-Contactor's backend process (see Fig. 1). The data is collected through a stopwatch time study. The standard time of each activity is calculated by considering the worker's working time, allowance time, and performance rating in the backend process. The concept of work sampling for labor productivity has been studied, e.g., by Hajikazemi [8]; Martinec et al. [9].

2.2 Machine downtime

In this case, there are two types of machine downtime, i.e., the scheduled and the unscheduled. The planned downtime takes 143 minutes or 2.38 hours per shift(see Table 1). Therefore, the planned downtime reduces the running time from 8 to 5.62 hours per shift. The unplanned downtime occurs occasionally. Table 2 summarizes the monthly estimated frequency and duration. Machine downtime is one of the leading causes that the maximum capacity is out of target.

Table 1. Average time for scheduled downtime activities

Downtime	Frequency	Duration (minutes)	Total time (minutes
SIM & 5D	1	36	35
Changeover /setup	2	20	40
ADM/ preparation	1	22	22
Trail Run/ Qualification	1	45	45
Total			143

Table 2. Some unscheduled downtime activities

Downtime	Monthly frequency estimate	Estimate duration (minutes)
Material shortages S/A	3-4	30
Machine breakdown	1-2	60
Training on bench	1-2	60
Defect product	0-1	104

Table.3 Preprocessing data for model simulation

Process	Allowance (%)	Standard time (second)	Fitted distribution
Functional Test	0,10	9,86	L(9.85, 0.048)
Dielectric Test	0,10	6,26	L(6.26, 0.073)
Assembly Cover & Paste Label	0,10	9,9	L(9.9, 0.053)
Laser Marking	0,10	3,88	L(3.88, 0,076)
Auto Unloading	0,10	8,86	L(8.86, 0.049)
Loading Product	0,10	6,24	L(6.24, 0.081)
Vision (Screw Reverse)	0,10	4,35	L(4.35, 0.098)
Resistance	0,10	10,09	L(10.09, 0.043)
Pusher 1	0,10	1,06	L(1.06, 0.070)
Unscrewing	0,10	9,94	L(9.94, 0.071)
Pusher 2	0,10	1,03	L(1.03, 0.086)
Vision (Cover)	0,10	1,12	L(1.12, 0.055)
Unloading Reject	0,10	4,16	L(4.16, 0.048)
Unloading Passed	0,10	4,13	L(4.13, 0.044)

Visual Check	0,20	7,38	L(7.38, 0.061)
Packing & Paste Label Auto	0,20	9,80	L(9.80, 0.055)

2.3 Distribution Fitted

We then fitted the standard time to the fittest statistical distribution. The fittest distribution will be used as the random generator distribution of the simulation input[10]. The distribution fitting is done using StatFit, embedded in the ProModel Simulation software [11, 12]. The preprocessing data is summarized in Table. 3. The fitted distribution for all activities is lognormal. The mean and standard deviation vary for each activity.

2.4 Model

The initial model of the K-Contactor Backend was carried out using ProModel 2011 software [13]. Several limitations in the initial model are:

- The entity used is a K-Contactor finished to after-tested products.
- Resource and Path Networks are not used because the working operators do not move while working.
- Unplanned Downtime is not included in reducing running time production on replication.
- Arrival time of the contactor entity is one second.

The initial model represents the current situation in the backend process before the layout is changed (see Fig. 2). The model is then verified and validated. The verification process compares the actual output results from the backend k-contactor line from July to December 2022 with the output results of 10 replications from the initial modeling. Model validation is carried out by direct modeling consultation with the relevant supervisor.

2. 5. Model Verification and Validation

A "verification model" in the simulation context typically refers to a model used to verify the correctness, accuracy, or performance of a simulation process or software. Simulation is creating a computer-based model or representation of a real-world system to study its behavior and analyze various scenarios [14].

Several steps to verify the model, including: Compare the conceptual flow diagram with the model in the simulation; View the process summary in the model and rematch the process logic; Matching animations to actual systems; Perform error compilation or debugging

The final step in the simulation is to validate the model. Model validation is essential for ensuring that the insights and predictions generated by a model are credible and applicable to real-world situations. It helps build confidence in the model's capabilities and enables better decision-making in fields where accurate representation of complex systems is crucial [15].

Before validating, the simulation must run in a steady state condition and meet the required number of replications. A warm-up time is required to set up the simulation in a stable state. Warm-up time can be determined by plotting the amount of output within a specific time.

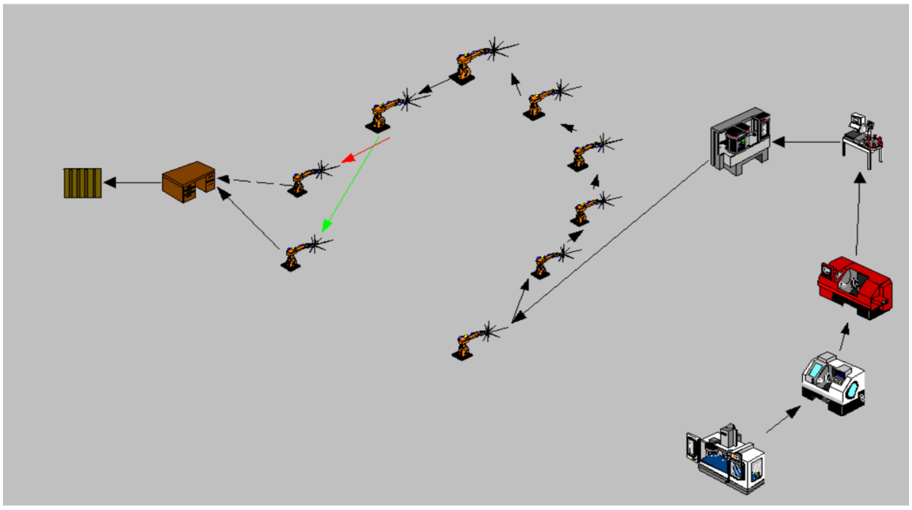


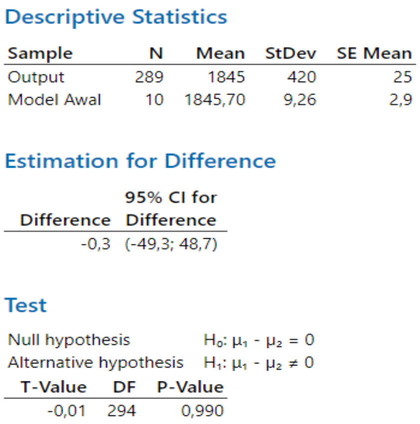
Fig. 2. Initial Layout Model.

3 Results and Discussions

The initial process of modeling (Figure 2) will start with the K-contactors arriving at the Functional Test. The dielectric test will follow that in the process. After passing the test, the K-Contactor will move on to the label and cover assembly stage, where the product will be labeled, and the material installed.

Run time is the duration of a model in carrying out a replication. In this study, the model run time is 5.61 hours according to the actual conditions of the backend. The run time represents the available production time per shift with the total Planned Downtime duration. The model is replicated ten times. The replication is adequate based on the adequacy test. The average production output is 1,836 K-contactor with a standard deviation of 10.52.

In the verification steps, we compare the actual output to the simulation output of the initiate model. The two-sample t-test p-value equals 0.99 (see Figure 3), which states that there is no significant difference between the actual output and the simulated one. Model validation is carried out by direct modeling consultation with the relevant supervisor. The supervisor validated that the model represents the actual condition.



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Descriptive Statistics

Sample          N      Mean   StDev   SE Mean
Output        289      1845     420        25
Model Awal     10   1845,70    9,26       2,9

Estimation for Difference

               95% CI for
Difference     Difference
      -0,3   (-49,3; 48,7)

Test

Null hypothesis          H₀: μ₁ - μ₂ = 0
Alternative hypothesis   H₁: μ₁ - μ₂ ≠ 0
T-Value    DF   P-Value
  -0,01   294     0,990
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Figure 3. The two-sample t-test output

This study proposed two step models. The first is adding one station in the resistance tester machine to reduce the bottleneck. The second proposal is to modify the robot by adding two screwdrivers. The robot will have four screwdrivers to minimize the sequence screwing from five times to only three times screwing.

The first proposed model allocates a robotic machine in a resistance tested device so that the device will increase from nine to ten devices. Initially, two functions were combined in one robotic machine or process. The proposed model divides the Resistance Tester process into two different methods or two different automatic devices (see Fig. 4).

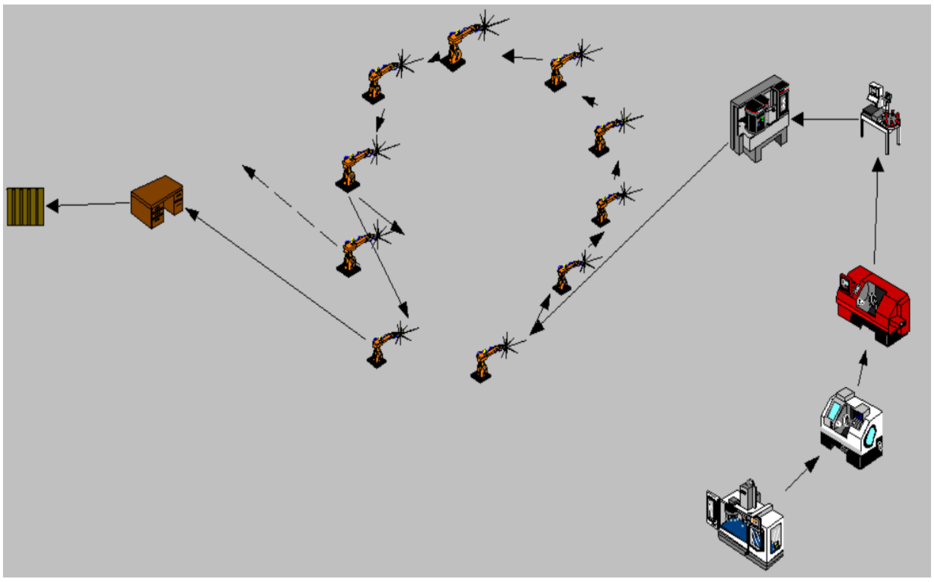

Fig. 4. The proposed layout model.

In the first step, the average K-contactor produced in the backend process increased to 332 pcs/hour. However, this result is still below the targeted output, i.e., 340 pcs/hour. Therefore, the second modification was applied to the first model by adding two more screwdrivers. This step will reduce the screwing sequence from five times to three times. As the results, the average of the unscrewing process is reduced from 9.94 seconds to 5.94 seconds and the average K-contactor produced in the backend process increased to 334 pcs/hour.

Additionally, the percentage of the efficiency coefficient is obtained from the history of computer log data in the backend line. It reaches 80%. It can be concluded that the efficiency coefficient has increased and reached company standards after implementing the proposed model. Table 4 summarizes total savings from projections for the next year, with a total nominal value of $31,892. After the projection of all savings from improvements has been obtained.

Tabel 4. Total project saving

Total project saving	2023
Saving by removing Operation Time (OT)	$25,267
Saving by Design Time (DT) reduction	$6,625
Total	$31,892

The cost required to implement all improvements from the first step, i.e., Resistance Improvement, is USD 35,000. Meanwhile, for the second step, the nominal is USD 25,000. The total costs incurred are USD 73,000. Since the total savings for twelve months is USD 31,892 (Table 4), the ROI will be 2.3 years (see Table 5).

Table 5. Return of Investment Calculation

Investment	Cost
Resistance Improvement	$35,000
Unscrewing Improvement	$25,000
Re-layout K-Contactor & Auxillaries	$7,000
Electrical Installation K-Contactor & Auxillaries	$6,000
Total	$73,000
Total Saving for 12 Months	$31,892
ROI	2.3 years

4 Conclusion

Reducing the cycle time in the K-Contactors Backend process can increase production capacity. When the proposed model is implemented, the K-Contactors backend process increases from 325 pcs/hour to 334 pcs/hour, and the Efficiency Coefficient (KE) increases by 80%. The total savings from reducing cycle time and removing overtime is USD 31,892. The estimated investment for improvements reached USD 73,000 with an ROI of 2.3 years. The future work of this study is to improve the model and to reduce the downtime so that the production line can reach the targeted capacity.

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